Carbon Ion Pump for Removal of Carbon Dioxide from Combustion Gas and Other Gas Mixtures

UCRL-ABS-218426

Roger D. Aines, William L. Bourcier, and Mackenzie R. Johnson

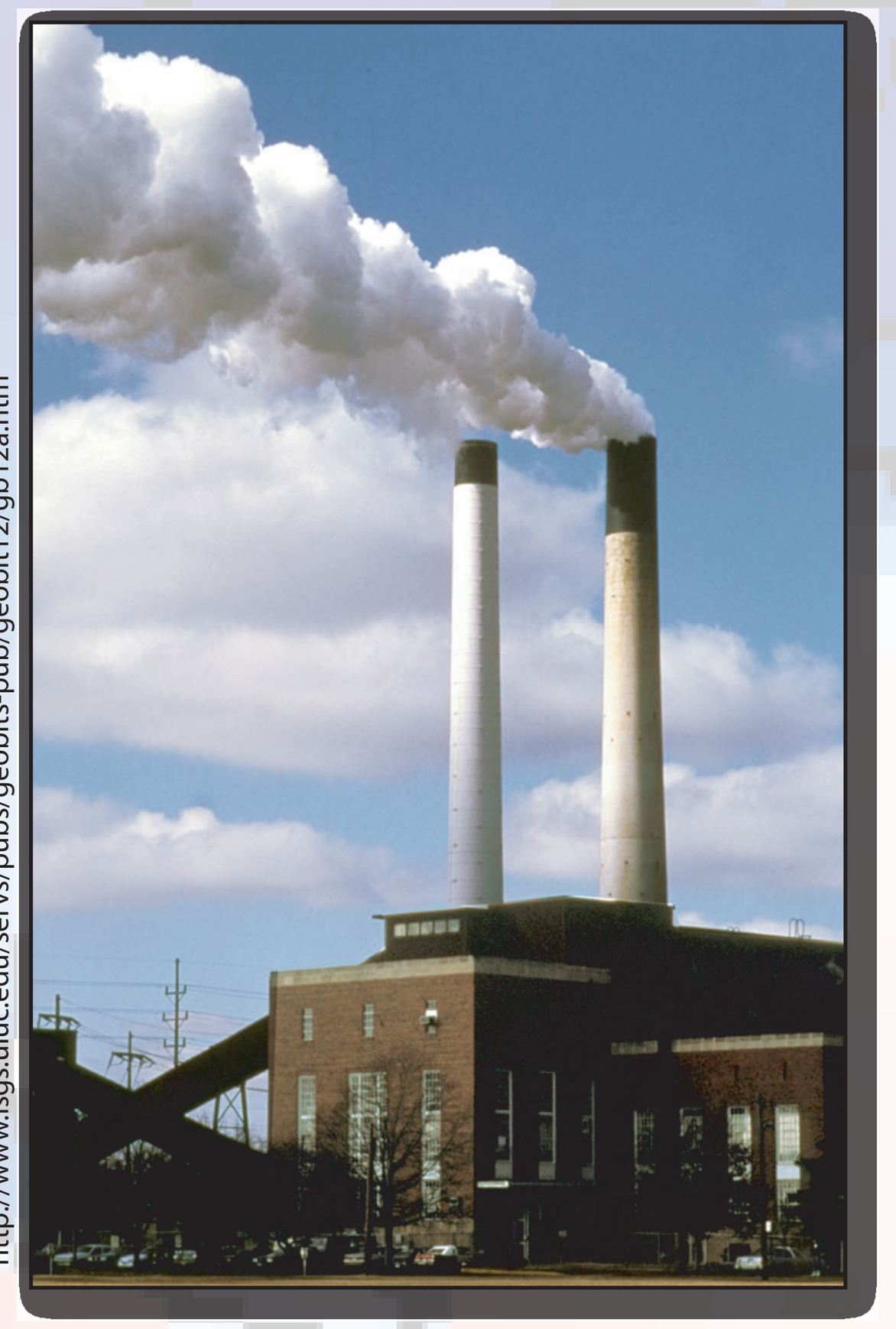
email at: aines1@llnl.gov 925-423-7184
7000 East Avenue, Livermore, California 94550-9234

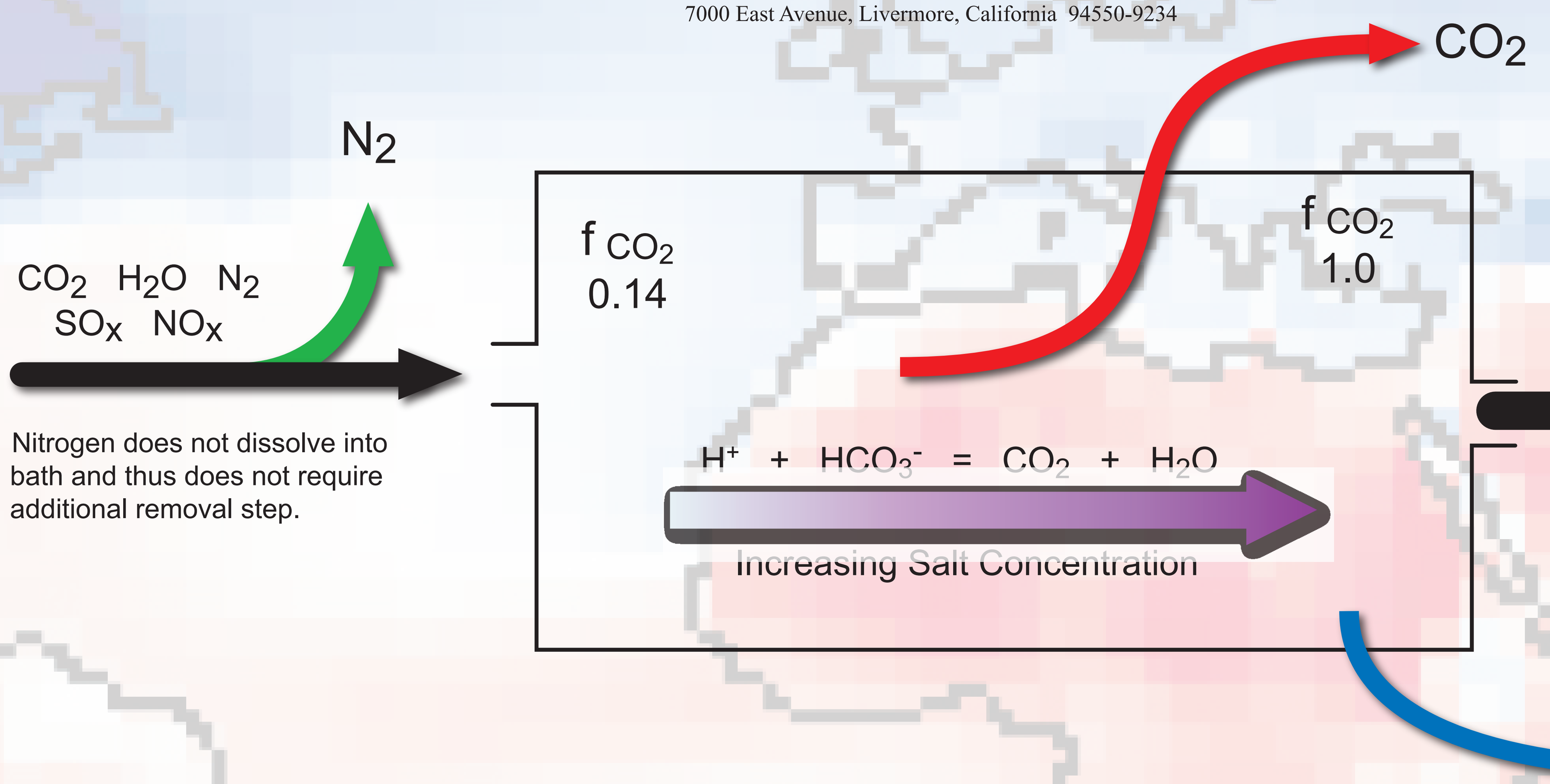
Abstract

We have developed a new method of separating carbon dioxide from flue gas. Instead of relying on large temperature or pressure changes to remove carbon dioxide from a solvent used to absorb it from flue gas, our method increases the concentration of dissolved carbonate ion in water. This increases the overlying vapor pressure (fugacity) of ™carbon dioxide gas, permitting it to be removed from the downstream side of the ion pump. The ion pumping may be obtained via reverse osmosis, electrodialysis, or other water purification methods.

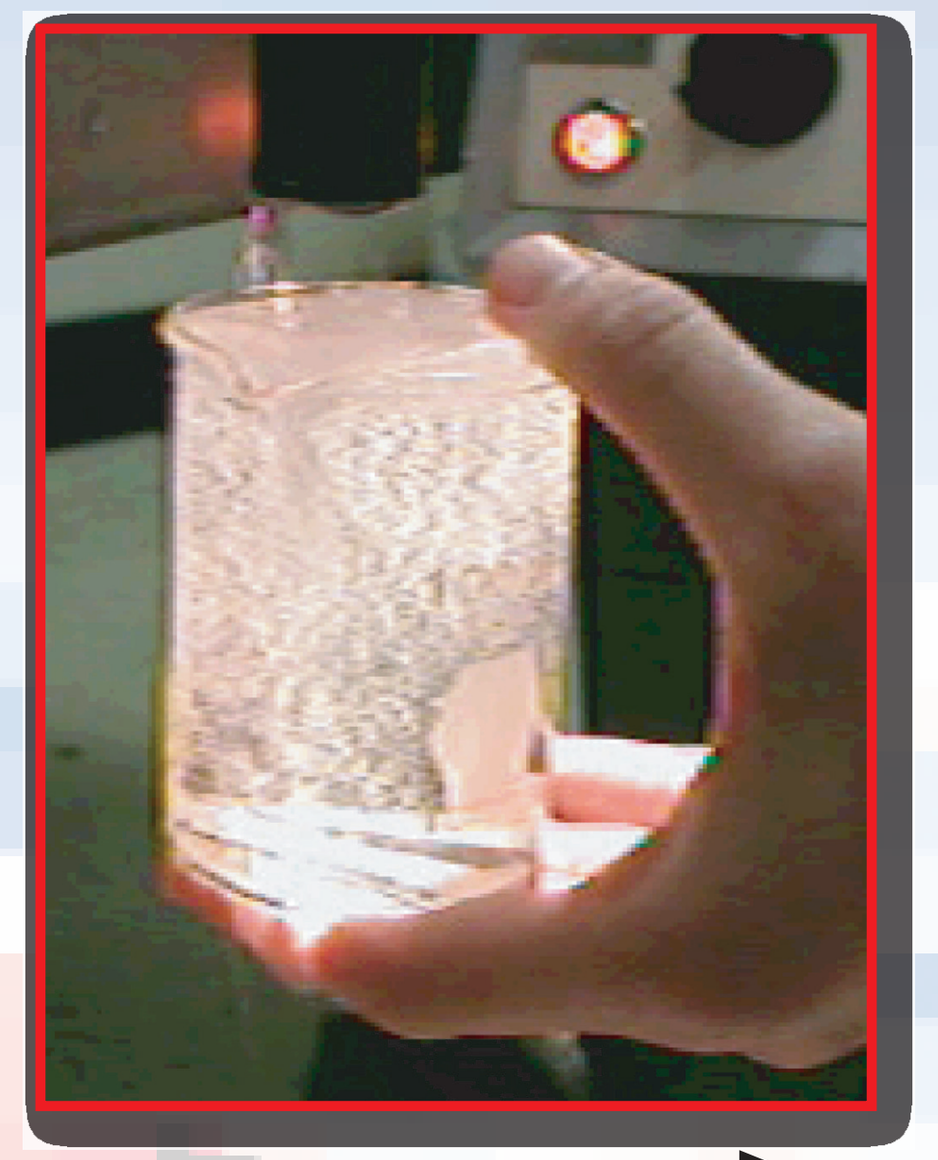
This novel approach to increasing the concentration of the extracted gas permits new approaches to treating flue gas and other gas mixtures of inert gas like nitrogen, with acid gases like carbon dioxide or sulfur dioxide, since the slightly basic water used as the extraction medium is impervious to trace acid gases that destroy existing solvents, and no pre-separation is necessary. The process may be operated in such a way to produce clean water (similar to reverse osmosis water) as an additional product.

The simple nature of the process lends itself to small separation plants. Although the energy cost of the ion pumping process is significant, we anticipate that it will be competitive with the current 35% energy penalty of chemical stripping systems in use at power plants to remove pure carbon dioxide for other use. There is the distinct possibility that the process could be dramatically more efficient. Our tests to date confirm that the method works with conventional water treatment equipment.

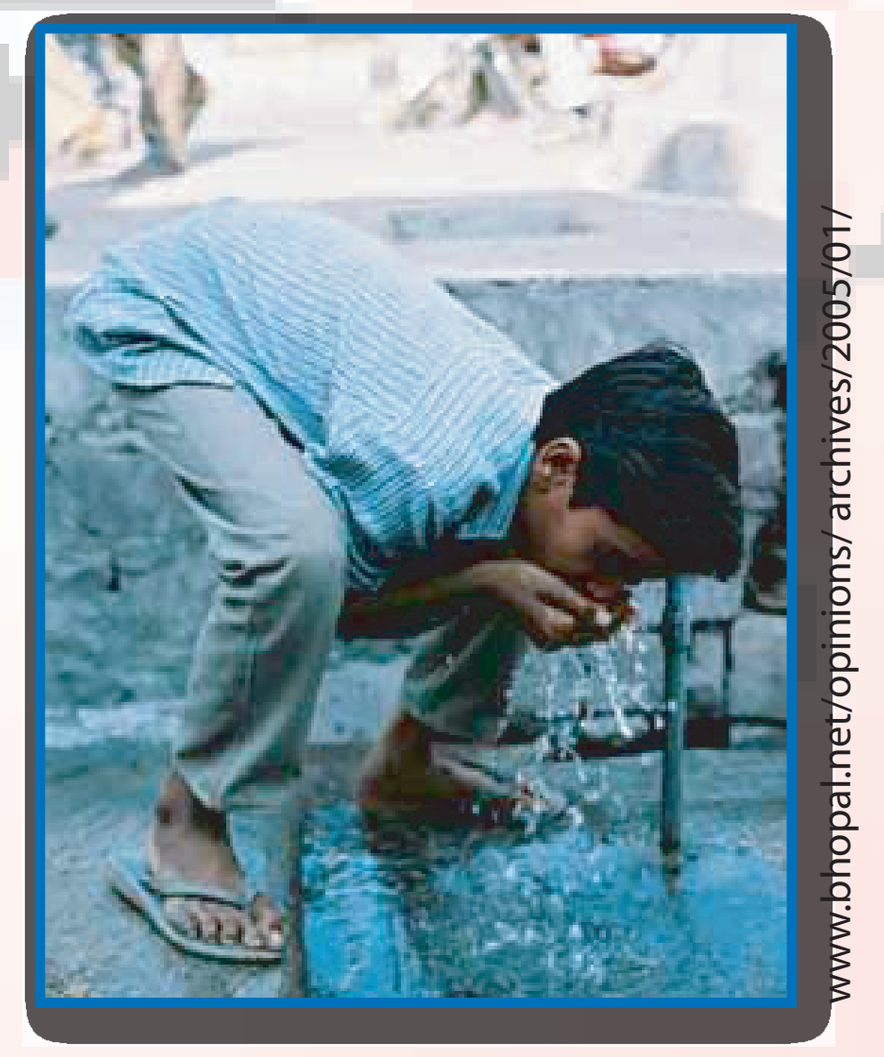




Nitrogen does not dissolve into bath and thus does not require additional removal step.

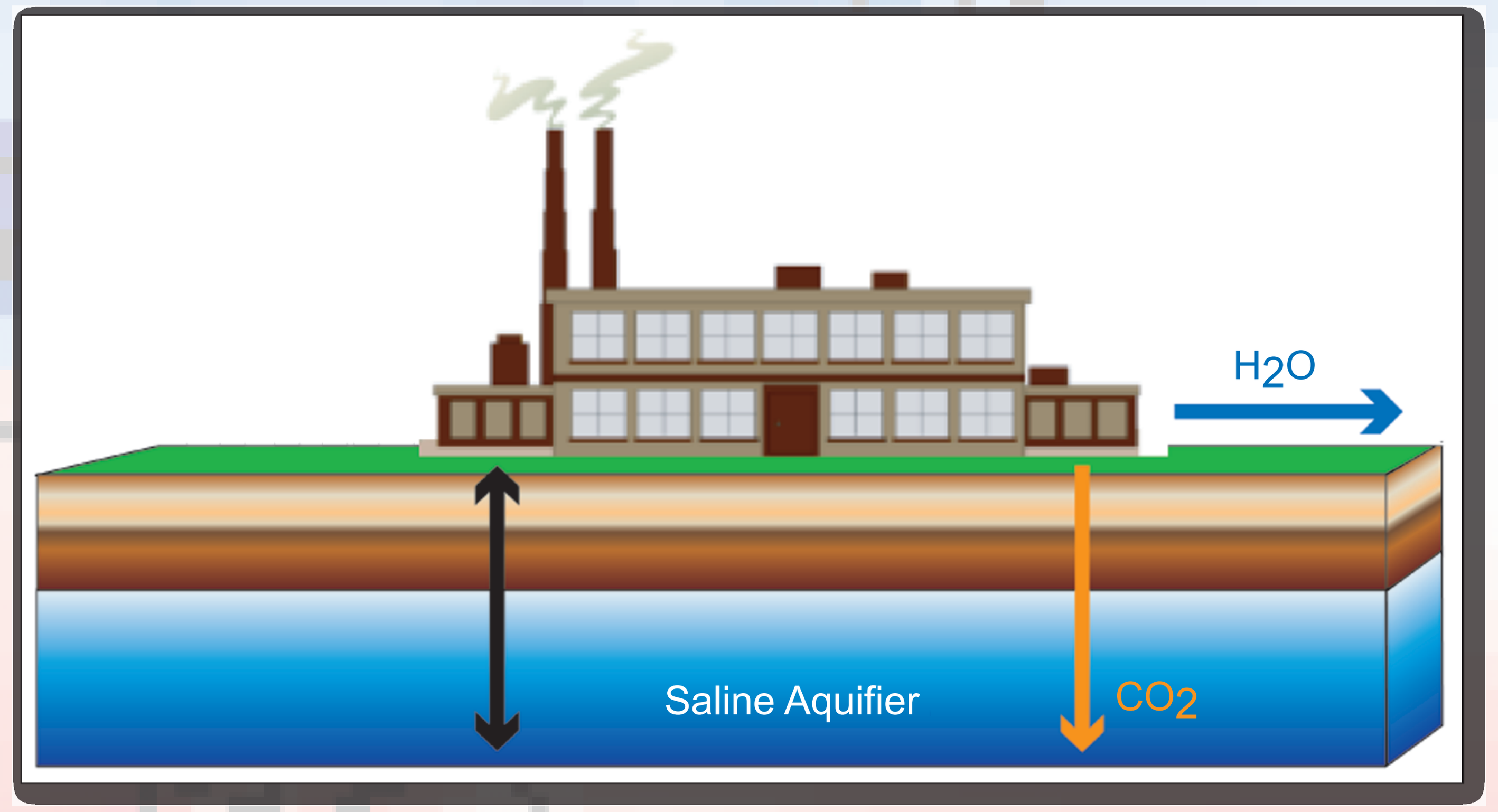


CO_2 effervescence during an experiment

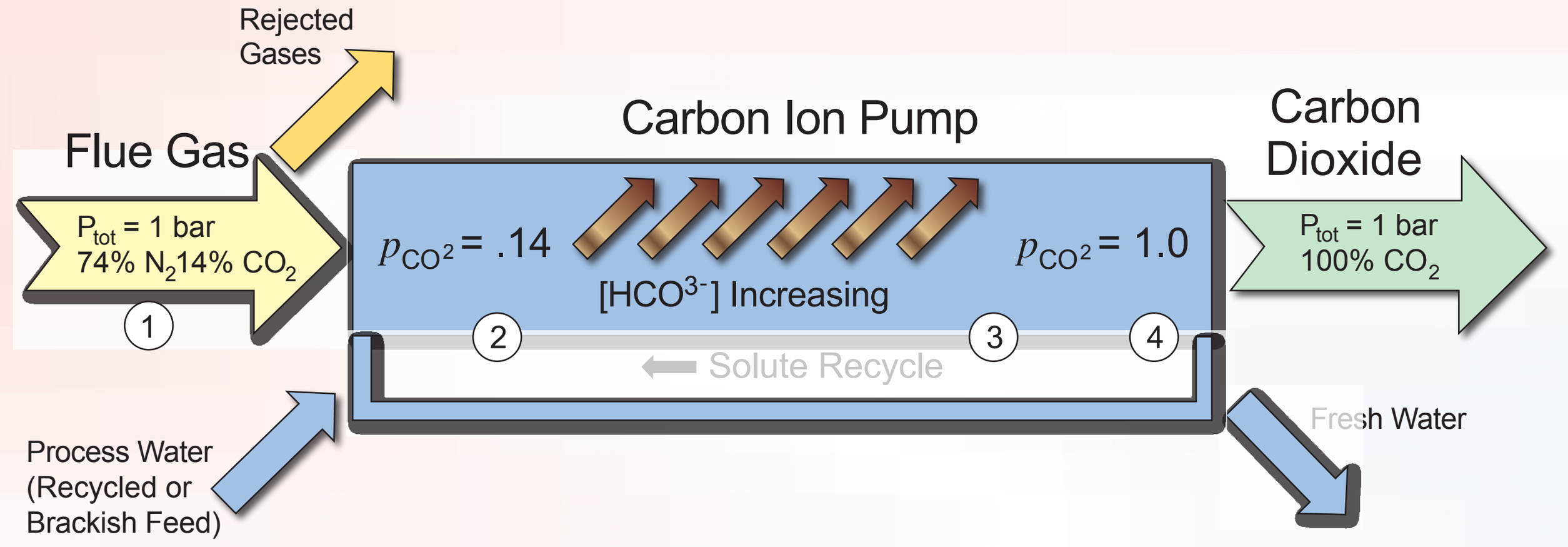


Conclusions and Future Work

– CO_2 can be seperated by a water-based process.
– Combined CO_2 separation and water purification is feasible.



Conceptual Description of the Method

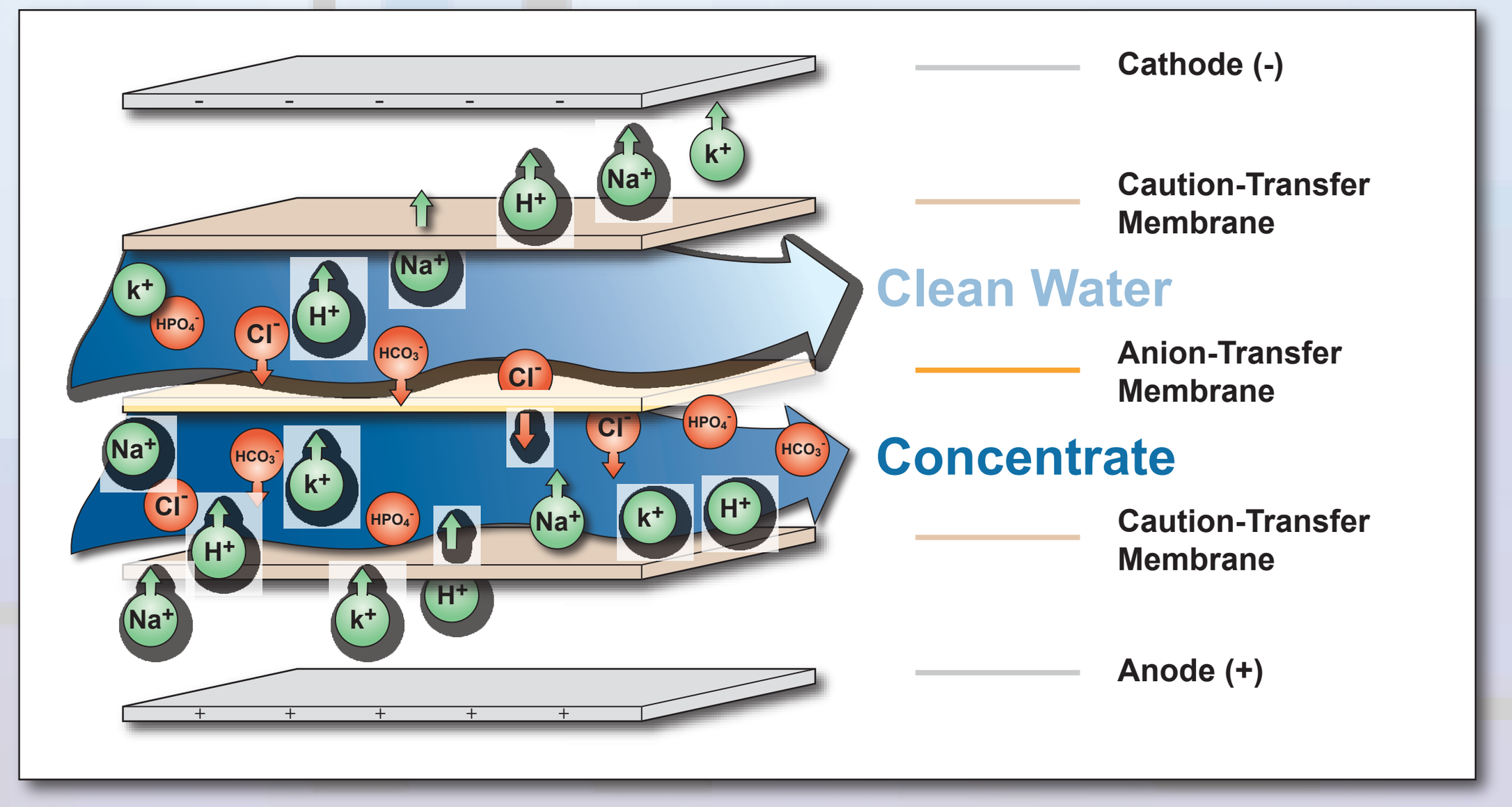


1. Carbon dioxide from flue gas dissolves in water-other gases pass through
2. Buffered process water carries CO_2 as carbonate and bicarbonate
3. Electrodialysis or reverse osmosis increases concentration of ions in solution
4. Carbon dioxide bubbles out when PCO_2 is greater than 1 bar

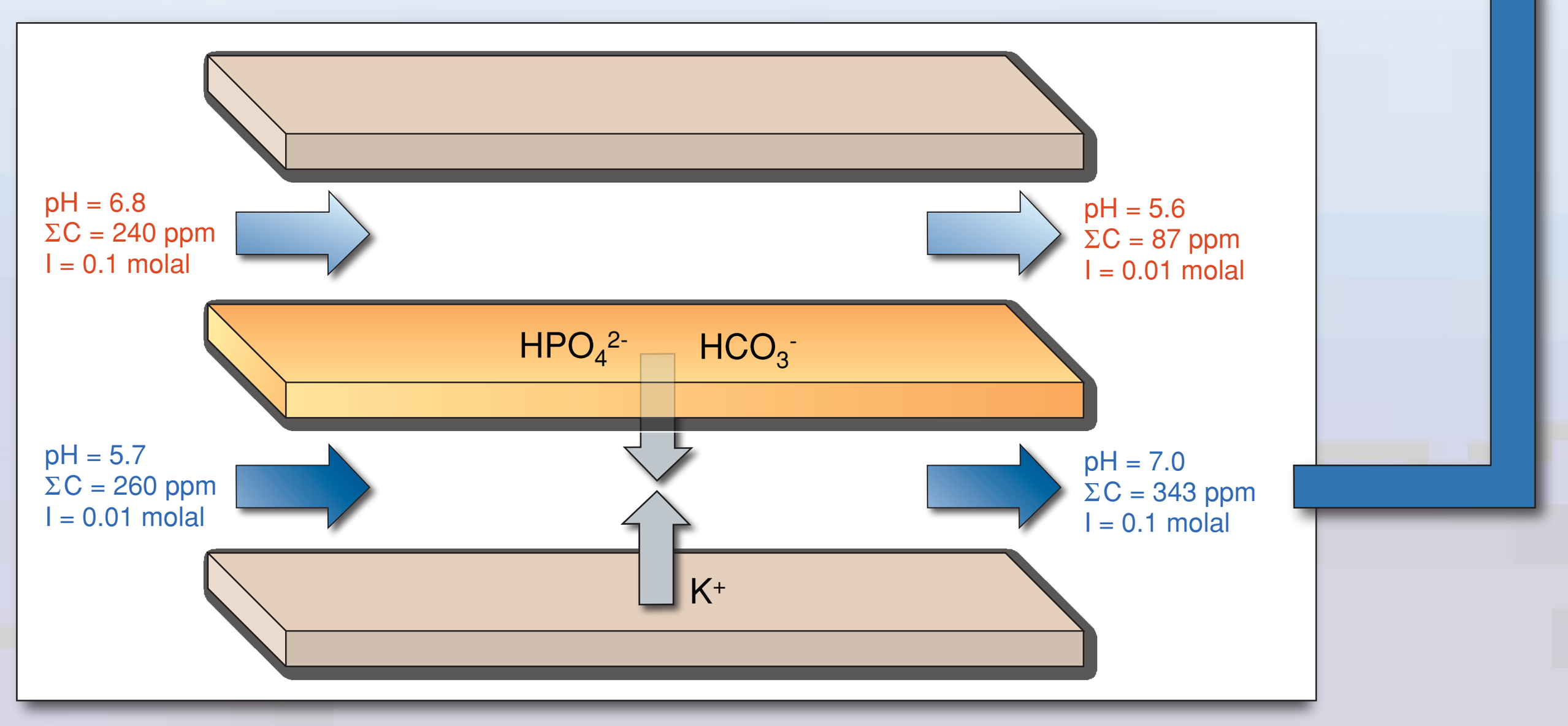
All experiments thus far have been conducted using an electrodialysis unit.

Future experiments include using reverse osmosis and a variety of gas mixtures.

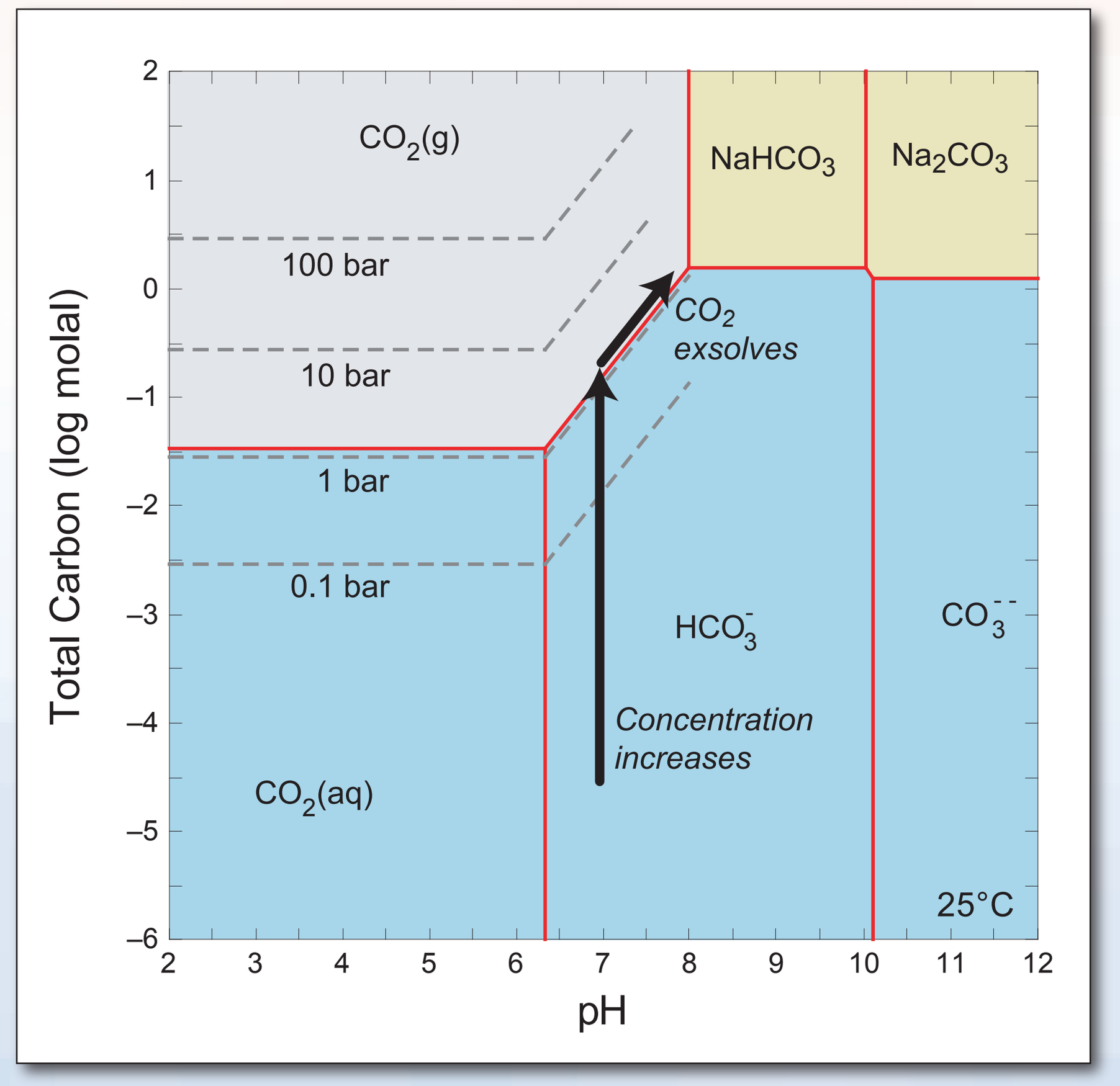
Electrodialysis concentrates salt in water using cation and anion selective membranes and a DC field



The existing setup allowed a one-pass treatment to increase total carbon in the concentrate and degas CO_2

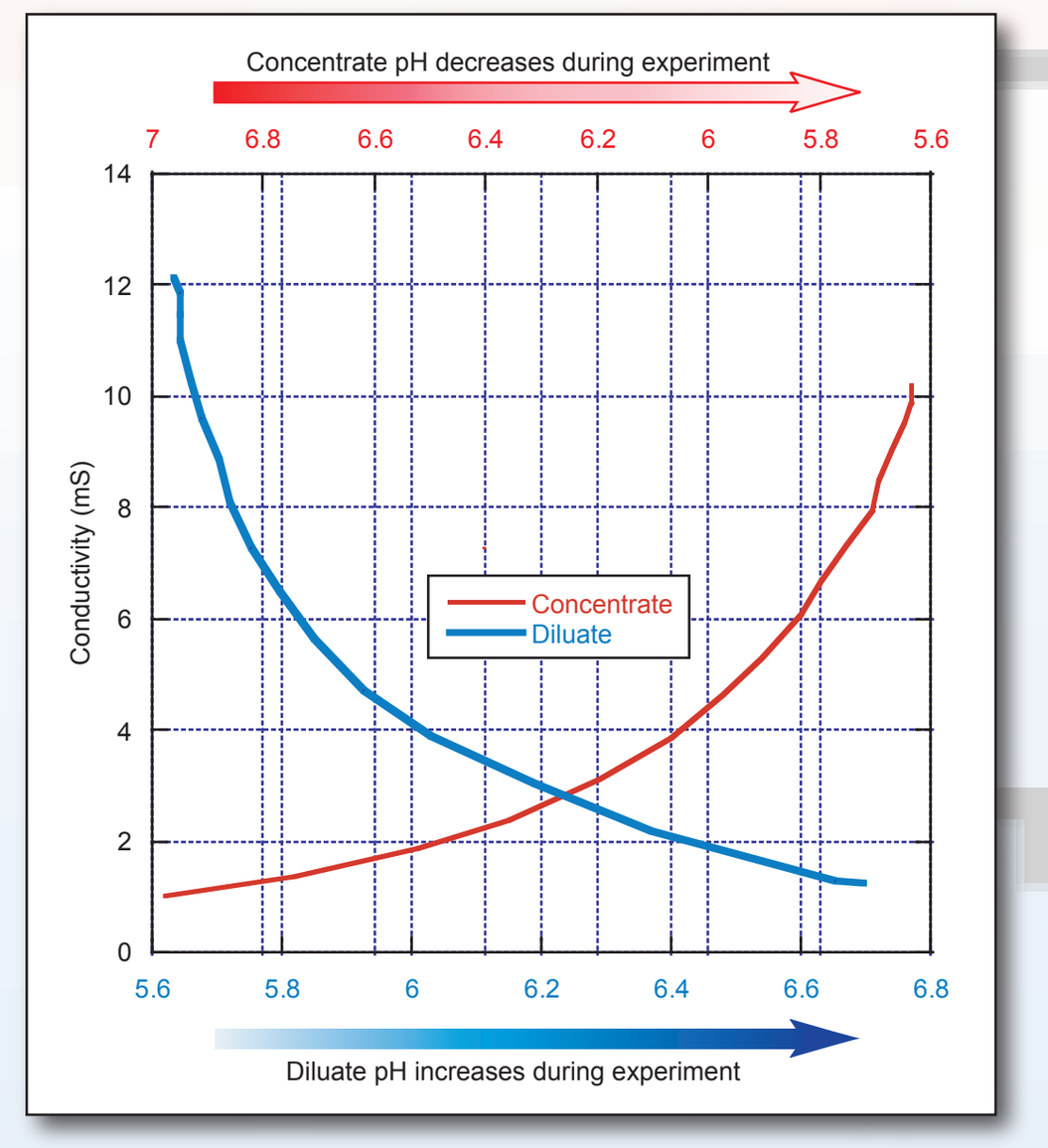


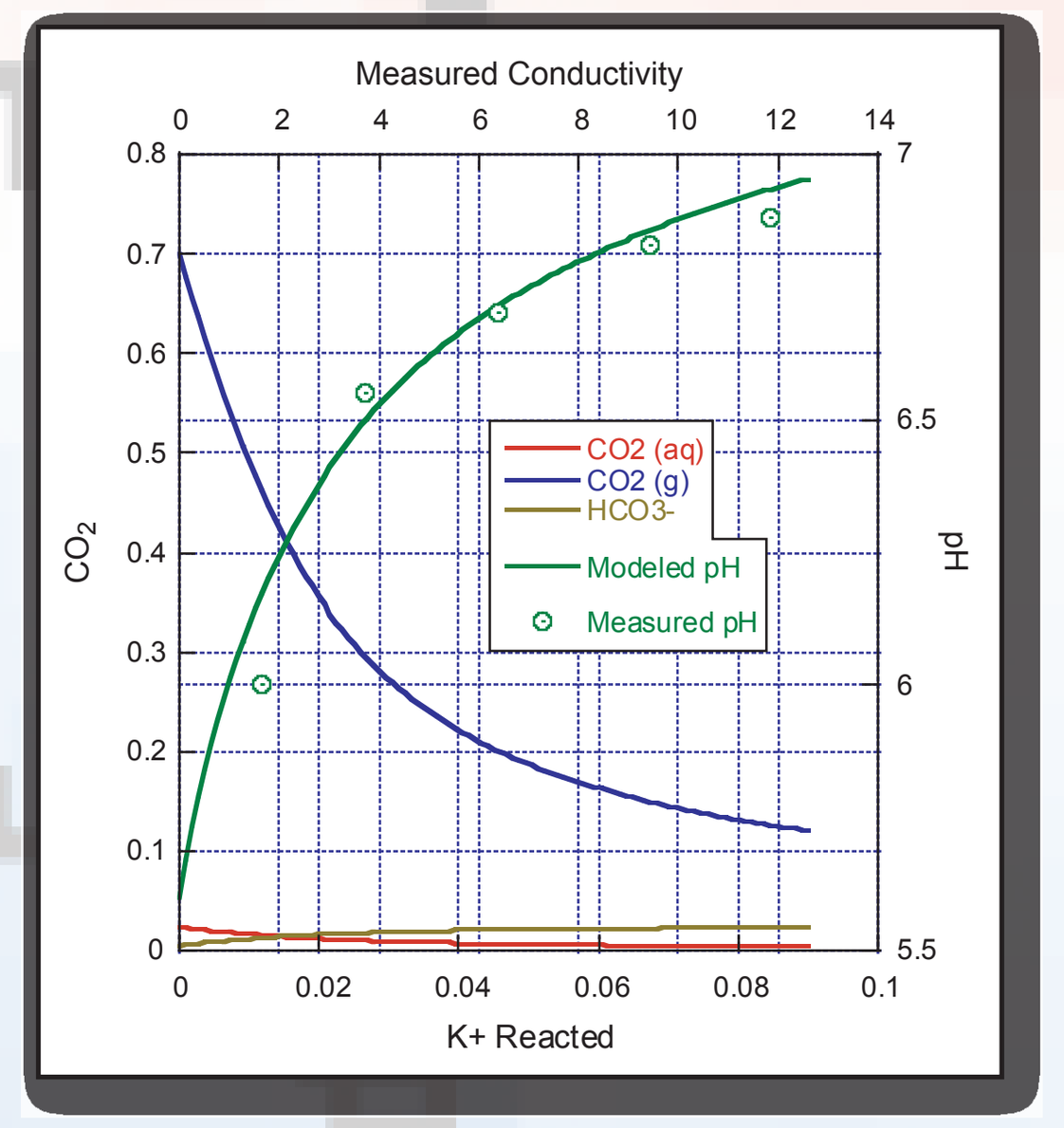
Results



Desalination increases the bicarbonate concentration and the fugacity coefficient of dissolved CO_2 resulting in a corresponding increase in CO_2 pressure. This “salting out” of CO_2 produces a nearly pure stream suitable for sequestration.

Assuming CO_2 exsolves at 1 bar, the system pH will start increasing as the CO_2 degases.





Parameters monitored during experiments:

T	Increased
pH	Increased in Diluate, Decreased in Concentrate
Conductivity	Decreased in Diluate, Increased in Concentrate

Comparing the actual experimental measurements with predictions based on modeling the process indicates that there is close agreement between actual and expected results. This validates using geochemical models to predict how desalination or other techniques will affect CO_2 removal.

We calculate that for flue gas from a coal-fired power plant, increasing the salinity by a factor of 30 will release 6.5 grams of pure CO_2 per liter of fluid.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.